

A Study of the Control of the Yellow-Dwarf Disease of Potatoes

E. D. Hansing



Published by the
Cornell University Agricultural Experiment Station
Ithaca, New York

Received for publication July 2, 1942

CONTENTS

	PAGE
Review of literature.....	3
Materials and methods.....	4
Experimental results.....	5
Comparative spread of yellow dwarf to different potato varieties and seedlings	6
Comparative spread of yellow dwarf to certain varieties of potatoes grown commercially.....	8
Effect of date of planting potatoes on the spread of yellow dwarf.....	9
Effect, on the spread of yellow dwarf, of isolating small plots of Green Mountain potatoes in different clover fields.....	10
Effect, on the spread of yellow dwarf, of isolating small plots of Green Mountain potatoes in different commercial fields.....	11
Comparative spread of yellow dwarf to Katahdin and Green Mountain potatoes isolated in various commercial fields.....	12
Effect of shielding crops, on the spread of yellow dwarf.....	12
Effect, on the spread of yellow dwarf, of the application of commercial fertilizer.....	13
Effect of spraying or dusting potatoes on the spread of yellow dwarf.....	14
Effect of roguing potatoes on the spread of yellow dwarf.....	15
Effect of date of harvesting on the control of yellow dwarf.....	15
Comparative spread of yellow dwarf to the margins of Rural potato fields adjoining different commercial crops.....	17
Comparative spread of yellow dwarf to the margins and centers of Rural potato fields.....	18
A summary of observations made during a survey of farms in Steuben County where certified Rural seed was introduced in 1939.....	18
The spread of yellow dwarf from adjoining fields into potatoes.....	20
Incidence of yellow dwarf in plants from tubers of various sizes.....	20
Comparison of the number of yellow-dwarf-infected plants obtained from different sections of Rural tubers.....	22
Diagnosis of yellow dwarf by slicing half-tubers compared with diagnosis by indexing.....	23
Diagnosis of yellow dwarf by slicing half-tubers as compared with diagnosis by mashing the slices and inoculating leaves of <i>Nicotiana rustica</i> ; and with diagnosis by indexing.....	24
Discussion.....	25
Summary.....	26
References.....	27

A STUDY OF THE CONTROL OF THE YELLOW-DWARF DISEASE OF POTATOES¹

E. D. HANSING

Before these investigations, a study had been made by Black (1937) on the yellow-dwarf disease of potatoes in New York. Such phases as the history, importance, and symptomatology of the disease, and the transmission of the virus were especially emphasized. Experiments were conducted to a limited extent on the life history of the insect, suspects of the virus, and the control of the disease. Since yellow dwarf was still the most important virus disease in west central New York, the logical sequence was to determine the most effective method in the control of the disease in that section of the state.

REVIEW OF LITERATURE

Barrus and Chupp (1922) observed yellow dwarf in 18 varieties of potatoes, none of which showed any resistance to the disease. They observed as many as 12 per cent infected plants in the variety Sir Walter Raleigh as compared with 5 per cent in each of the varieties Green Mountain and Manistee. Fernow and Black (1932) reported that yellow dwarf was more abundant in fields of Green Mountain than of Rural potatoes. Wheeler (1936) and Taylor (1938) found that certain potato-seedling varieties escaped natural infection of yellow dwarf. Black (1937) artificially inoculated different named varieties and 17 United States Department of Agriculture potato-seedling varieties. He found that none of them was immune to yellow dwarf.

Taylor (1938) reported considerable variation in the spread of yellow dwarf to different varieties of potatoes. He obtained as few as 6.4 per cent infected plants in Russet Burbank as compared with 48.4 per cent in Columbia Russet. Walker and Larson (1939) reported a moderate spread (missing hills and infected plants) of yellow dwarf to Russet Burbank (18 per cent), Warba (28 per cent), and 100-Day Cobbler (33 per cent). The other 16 varieties and strains of potatoes they studied had from 48 to 81 per cent of infected plants and missing hills.

Several methods have been tried to a limited extent in the control of yellow dwarf. Various workers have suggested the use of virus-free tubers for seed (Muncie, 1935; Black, 1937; Larson and Walker, 1938). This method, however, was not very satisfactory because there was often sufficient current-season infection² so that the grower had to purchase virus-free tubers the following year. Black (1937) obtained an average of 4.4 per cent of infected plants by indexing tubers from small plots of Green Mountain potatoes planted next to clover fields, as compared with 1.7 per cent from small plots isolated in the center of oat fields. He also observed that

¹Also presented to the Faculty of the Graduate School of Cornell University, September 1941, as a major thesis in partial fulfillment of the requirements for the degree of doctor of philosophy.

AUTHOR'S ACKNOWLEDGMENTS. The writer wishes to express his sincere appreciation to his major professor, Dr. F. M. Blodgett, for his many helpful suggestions during the progress of this research and in the preparation of the manuscript. He is also indebted to Dr. K. H. Fernow and to Dr. V. L. Frampton for their interest and constructive criticism during this study.

²Current-season infection is primary infection, or infection following transmission of the virus to potato plants by the vector. Seed-borne infection is secondary infection on potato plants grown from infected tubers.

there was a higher current-season spread of yellow dwarf to potatoes near the margin of the field than to those in the center. This was especially evident when the margin was adjacent to second- or third-year clover. This explained why the use of potato-seed plots had not been satisfactory as a means of control.

Roguing of the current-season infected plants reduced the amount of disease from 33 to 22 per cent (Black, 1937). A highly significant reduction in infected plants was obtained by spraying potatoes with bordeaux mixture (infection reduced to 0.3 per cent for the sprayed as compared with 3.3 per cent for the check) (Mader and Watkins, 1938). Reductions in the percentages of infected plants were also obtained by spraying or dusting with pyrethrum, sulfur, bordeaux mixture plus pyrethrum, or bordeaux mixture plus sulfur (Watkins, 1939).

Black (1937) found no significant difference in infected plants from tubers graded large or small. He found that the number of half-tubers which showed yellow-dwarf specks multiplied by the factor 1.3 was a fairly good indication of the percentage of infected tubers. Transmission of the disease to potatoes during cutting and planting operations was negligible or absent. Walker and Koch (1934) and Black (1937) found that yellow-dwarf and healthy plants often developed from different sections of the same tuber.

Mader (1937), in a general survey of New York state, observed that yellow dwarf was restricted chiefly to those areas where Medium Red clover was grown. He suggested the possibility of controlling this disease through the elimination of this clover. He stated that in the areas where yellow dwarf was severe, alfalfa, Mammoth Red clover, and perhaps other clovers could be planted until subsequently found to be susceptible to the yellow-dwarf virus. In Wisconsin, Walker and Larson (1939) found no correlation between red-clover fields and epiphytotics of the disease.

Hansing and Frampton (1940) found that the incidence of yellow dwarf in potato fields indicated that the clover-leaf-hopper vector migrated in obedience to the laws of diffusion. They concluded that the principal vector occurred naturally outside the field in question, and that the spread of yellow dwarf from potatoes infected during the current season was of minor importance.

MATERIALS AND METHODS

The majority of the experiments included in this investigation were conducted in the north third of Steuben County and in the adjacent southeast portion of Livingston County. Since 1930, yellow dwarf has been more severe and prevalent in this central section of western New York than in any other locality in the state. A few experiments were conducted in Tompkins County on the farm of Dr. Karl Fernow near Ithaca, New York.

The Green Mountain seed³ used in these experiments was purchased from growers of certified potatoes on Prince Edward Island. Certified Katahdin seed, Chippewa seed, and Warba seed were purchased from commercial companies. Dr. Karl Fernow furnished the potato seed of the seven varieties used in one of the variety tests on his farm. The other varieties and the United States Department of Agriculture potato-seedling varieties were furnished by Dr. J. R. Livermore, Department of Plant Breeding, Cornell University.

³The term *seed* will be used in reference to tubers used for propagation.

All the field experiments were conducted in cooperation with growers of either certified or non-certified potatoes who were interested in finding a satisfactory control of yellow dwarf. On each farm the majority of the experiments were conducted in places where, under proper environmental conditions, a medium to high current-season spread of yellow dwarf could be expected. Most of the treatments in the various experiments were replicated from two to four times.

The potatoes in the various experiments were dug either after the vines were dead or after the first killing frost. In this way, the maximum current-season spread of yellow dwarf was obtained.

The potato samples were kept in artificial cold storage until a short time before they were to be planted. All the samples in 1938 and some of the samples in 1939 were indexed in the greenhouse at Ithaca. The temperature in the greenhouse was maintained at 18° C. until most of the potato plants had emerged. The temperature was then raised to, and kept at, 25° C. until the plants were discarded. Notes were taken on each group of plants at three different times to be certain that all infected plants would be recorded. Since there were very few missing hills, these were disregarded in calculating the percentages of infected plants.

The majority of the samples were planted in a field near Ithaca. Whole tubers were planted by means of a special attachment on the potato planter. The average stand from most of the samples was approximately 97 per cent. The missing hills were disregarded in determining the percentages of infected plants because there was very little difference in this respect between the samples which had many infected plants and those which had none. A few of the samples were planted in another field in fairly wet soil. Excessive rains followed and a few of the tubers rotted. The missing hills were disregarded in the calculations for this field because there was no apparent correlation between them and yellow-dwarf infection.

Most of the data were analyzed statistically. The percentages of infected plants were transformed to angles and then treated by analysis of variance (Snedecor, 1940). Other data were analyzed by analysis of variance, Chi-square, or Student's "t". Regression lines were determined by least squares (Ezekiel, 1930). The tables of Fisher and Yates (1938), Pearson (1924), and Snedecor (1940) were used in determining the odds for significance.

EXPERIMENTAL RESULTS

Yellow dwarf has been the most difficult to control of the virus diseases of potatoes in west central New York. Although mosaic, leafroll, and spindle tuber have been effectively controlled by the use of good foundation stock, this practice has not been effective in the control of yellow dwarf. In the severely diseased, yellow-dwarf area of western New York, in seasons following the years when environmental conditions have been favorable for high current-season spread of yellow dwarf, neither growers of certified nor growers of non-certified potatoes have controlled the disease.

In view of the published data on the disease and on the clover leafhopper, and the interrelationship of the two, a number of types of experiments were conducted to determine the relative value of various measures suggested for the control of yellow dwarf.

COMPARATIVE SPREAD OF YELLOW DWARF TO DIFFERENT
POTATO VARIETIES AND SEEDLINGS

Because no potato varieties or United States Department of Agriculture potato-seedling varieties were immune to yellow dwarf when inoculated artificially (Black, 1937), the control of this disease by the use of resistant varieties of potatoes had not seemed promising at first. During the summer of 1938, however, no current-season spread of yellow dwarf was observed in a 0.3-acre field of Katahdin potatoes in Livingston County, but there was considerable spread of the disease to the 14 acres of Green Mountain potatoes grown on the same farm.

A representative sample of 100 tubers was taken from each variety. These were indexed⁴ in the greenhouse during the winter. All the Katahdin plants were healthy while 15 per cent of the Green Mountain plants were infected with yellow dwarf. Similar results were obtained by Dr. Karl Fernow in the Florida potato tests of the New York Seed Improvement Cooperative Association.

Because Katahdin and Green Mountain potatoes were susceptible to yellow dwarf when inoculated artificially, and because there was so much difference in the comparative spread of the disease to these two varieties, fairly extensive variety tests were started.

Seven replicated variety tests were conducted in 1939 on five farms in three counties to determine whether there was any difference in the comparative spread of yellow dwarf to different commercial and seedling varieties. Because the principal purpose of these experiments was to obtain the maximum amount of yellow-dwarf infection, the plots were located either in the center of or next to a meadow in such a way that no variety in any experiment was located more than 13 rows from a source of inoculum. The varieties and seedlings were planted in 25-hill units and 4 replicates were used in most of the experiments. A systematic arrangement was used, although it is now recognized that there are serious objections to this type of arrangement. Because the arrangement was different in each place and the results were fairly consistent, they are believed to be reliable in spite of this defect in arrangement. The potatoes were dug by hand the latter part of October, and a representative sample of approximately fifty 2- to 4-ounce tubers was saved from each 25-hill unit. These were indexed during 1940.

The varieties Jubel, Katahdin, Warba, Chippewa, Houma, Sebago, Arran Banner, and Golden had from 0.0 to 1.9 per cent of infected plants in the various experiments (figure 1). In contrast, Russet Burbank had from 2.0 to 11.0 per cent, Rural had from 2.9 to 21.1 per cent, Russet Rural had from 4.2 to 29.1 per cent, Green Mountain 6.0 to 52.2 per cent, and Red McClure, which was included in only one experiment, had 51.6 per cent of infected plants.

In one experiment Russet Burbank had significantly⁵ more infected plants

⁴The term *indexed* will be used in reference to planting whole tubers from the representative samples and later observing the percentage of infected plants.

⁵Significant = odds greater than 19:1.

Highly significant = odds greater than 99:1.

Very highly significant = odds greater than 999:1.

than Jubel, Katahdin, Warba, Chippewa, or Houma. There was no significant difference in infection among Early Bovee, Rural, Rural (No. 9), and Russet Rural. In those experiments, however, in which there was a high spread of yellow dwarf, these latter four varieties had significantly more infected plants than the varieties Russet Burbank, Jubel, Katahdin, Warba, Chippewa, and Houma. Of the varieties of potatoes grown commercially in New York, Green Mountain had the highest percentage of infected plants. Red McClure, grown principally in Colorado, had significantly more infected plants than Green Mountain. The percentages of infected plants of the United States Department of Agriculture seedling varieties were fairly well distributed among the commercial varieties (figure 1).

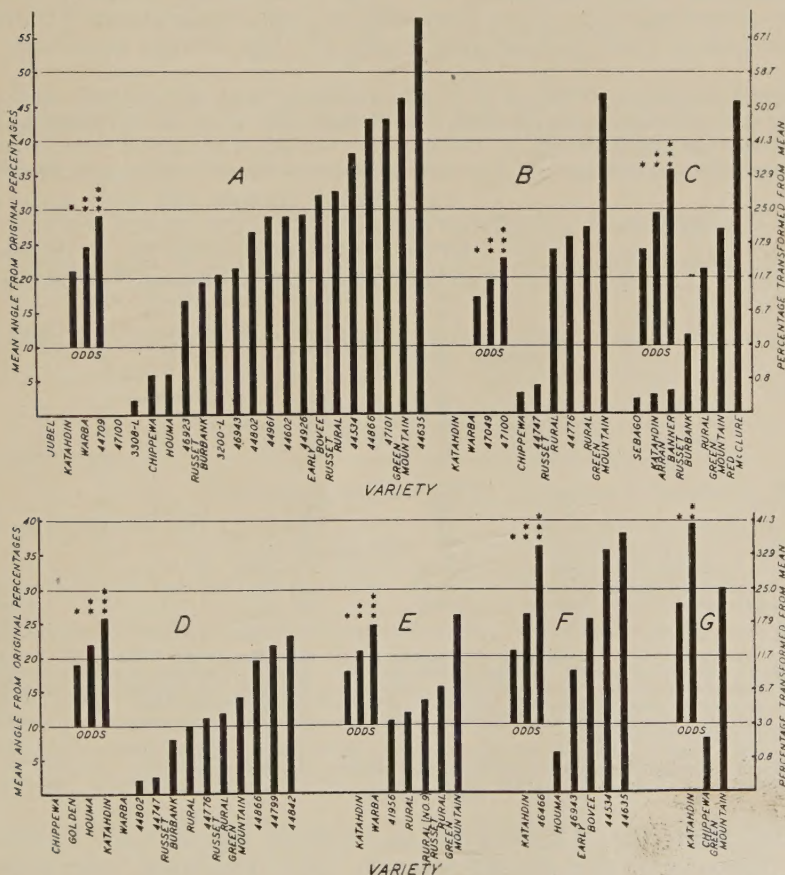


FIGURE 1. COMPARATIVE SPREAD OF YELLOW DWARF TO DIFFERENT POTATO VARIETIES AND SEEDLINGS (STEUREN, LIVINGSTON, AND TOMPKINS COUNTIES), PLANTED 1939, INDEXED 1940

The lengths of the bars below the asterisks indicate the differences necessary for significance with odds of 19:1, 99:1, and 999:1.

COMPARATIVE SPREAD OF YELLOW DWARF TO CERTAIN VARIETIES
OF POTATOES GROWN COMMERCIALY

A survey was made during July and August, 1940, to determine the comparative spread of yellow dwarf to certain varieties of potatoes grown commercially in Steuben County. The farms were selected at random in the northern third of the county where yellow dwarf had been very severe. On all of the farms included in this survey both Rural and Katahdin varieties were grown during 1939 and 1940. Notes were taken on a total of 1000 potato plants at 5 different locations in each field. If no infected plants were found in the 1000 plants counted, but were subsequently found in the field, it was recorded as a trace.

The yellow-dwarf infection in the Rural fields on the 15 farms in this survey varied from 6 to 41 per cent, while the yellow dwarf in the Katahdin varied from a trace to 2 per cent (table 1). The average percentage of

TABLE 1. COMPARATIVE SPREAD OF YELLOW DWARF TO CERTAIN VARIETIES OF POTATOES GROWN COMMERCIALY DURING TWO CONSECUTIVE YEARS ON THE SAME FARM, STEUBEN COUNTY, 1939-40*

Cooperator	Variety			
	Rural	Katahdin	Chippewa	Sebago
	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>	<i>Per cent</i>
F.....	6	Trace†	Trace	.....
G.....	6	Trace	.....	.....
H.....	8	Trace	Trace	Trace
I.....	9	Trace	Trace	.....
J.....	9	0.5	.....	.....
K.....	12	Trace	Trace	.....
L.....	12	Trace	.....	.....
M.....	14	1.0	.....	.....
N.....	17	0.3	.....	.....
O.....	19	0.1	.....	.....
P.....	19	Trace	.....	.....
Q.....	22	Trace	Trace	.....
R.....	28	0.3	.....	.....
S.....	31	2.0	.....	.....
T.....	41	1.0	.....	.....
Mean angle from original percentages‡	23.45	2.12	0.0	.....
Percentage transformed from angle....	15.8	0.14	0.0	.....

*The commercial fields represented in this survey include only those in which Rural and Katahdin potatoes were grown on the same farm during 1939 and 1940. They were selected at random in the section of Steuben County where yellow dwarf was most severe. The notes taken during July and August, 1940, represent the comparative spread of yellow dwarf to these varieties during 1939.

The majority of the fields of Katahdins contained a slight mixture of Rural potatoes. No correction was made for this variable factor.

†No yellow dwarf found in first 1000 plants counted, but later observed in the field.

‡Difference in angle between Rural and Katahdin significant, odds greater than 999:1.

§Difference in angle between Rural and Chippewa significant, odds greater than 99:1.

infected plants was 15.8 for Rural as compared with 0.14 for Katahdin. The difference between the two was very highly significant (odds greater than 999:1).

Chippewa potatoes were grown on 5 of these farms. On these five farms, 6 to 22 per cent of infected plants were found in the Rural potato fields as compared with only a trace in the Chippewa fields. The average percentage of infected plants in the Rural fields was 10.9 as compared with a trace in

the Chippewa fields. The difference was highly significant. The variety Katahdin had only a trace of yellow dwarf on these five farms.

The variety Sebago was grown on one farm. There were eight per cent of infected plants in the Rural field on this farm as compared with only a trace in the Katahdin, Chippewa, and Sebago fields.

Rural strains of potatoes were grown on more than 95 per cent of the acreage of potatoes in this section of New York in 1939. The majority of the potato growers planted only a small acreage of Katahdin, Chippewa, and Sebago. Most of the Katahdin fields surveyed in 1940 had a mixture of Rural potatoes (from a trace to a few per cent). Because it was impossible in most cases to tell the variety of infected plants, no correction could be made for this variable factor.

EFFECT OF DATE OF PLANTING POTATOES ON THE SPREAD OF YELLOW DWARF

Two experiments were conducted in 1939 to determine the effect of date of planting potatoes on the spread of yellow dwarf. Katahdin, Chippewa, and Green Mountain potatoes were planted in 25-hill plots, on two farms. The plantings were made on various dates in May and June. The progeny of these plots was indexed during 1940.

The percentages of infected plants for the different dates of planting varied from 0.0 to 2.2 for Katahdin, from 0.0 to 4.5 for Chippewa, and from 2.1 to 77.8 for Green Mountain (table 2). There was a significant correlation

TABLE 2. EFFECT OF DATE OF PLANTING POTATOES ON THE SPREAD OF YELLOW DWARF, STEUBEN COUNTY, 1939-40*

Date of planting	Cooperator C			Cooperator A		
	Variety			Variety		
	Katahdin	Chippewa	Green Mountain†	Katahdin	Chippewa	Green Mountain†
	<i>Per cent infected plants</i>	<i>Per cent infected plants</i>	<i>Per cent infected plants</i>	<i>Per cent infected plants</i>	<i>Per cent infected plants</i>	<i>Per cent infected plants</i>
May 19.....	1.9	4.5	77.8	...	...	...
May 27.....	2.2	3.3	56.5	0.0	1.6	31.5
June 4.....	0.0	3.6	75.6	0.0	0.0	18.0
June 12.....	0.0	4.2	16.7	0.0	2.0	23.6
June 20.....	0.0	2.0	23.2	0.0	0.0	21.3
June 28.....	0.0	0.0	9.6	0.0	0.0	13.0
July 6.....	0.0	0.0	3.5	0.0	0.0	2.1
July 14.....	0.0	0.0	7.5	0.0	0.0	7.0
Mean angle from original percentages†.....	2.06	7.70	33.58	0.0	2.20	22.94
Percentage transformed from mean.....	0.13	1.8	30.6	0.0	0.15	15.2

*Planted in small square plots isolated in a meadow on each farm, 1939; indexed, Ithaca, New York, 1940.

†Difference in angle between dates is not significant, but there is a significant correlation between dates and the amount of yellow dwarf expressed in equivalent angles in the Green Mountain variety.

‡Difference in angle between Green Mountain and either Chippewa or Katahdin significant, odds greater than 999:1.

between dates and the amount of yellow dwarf expressed in equivalent angles in the Green Mountain variety (figure 2). The difference between

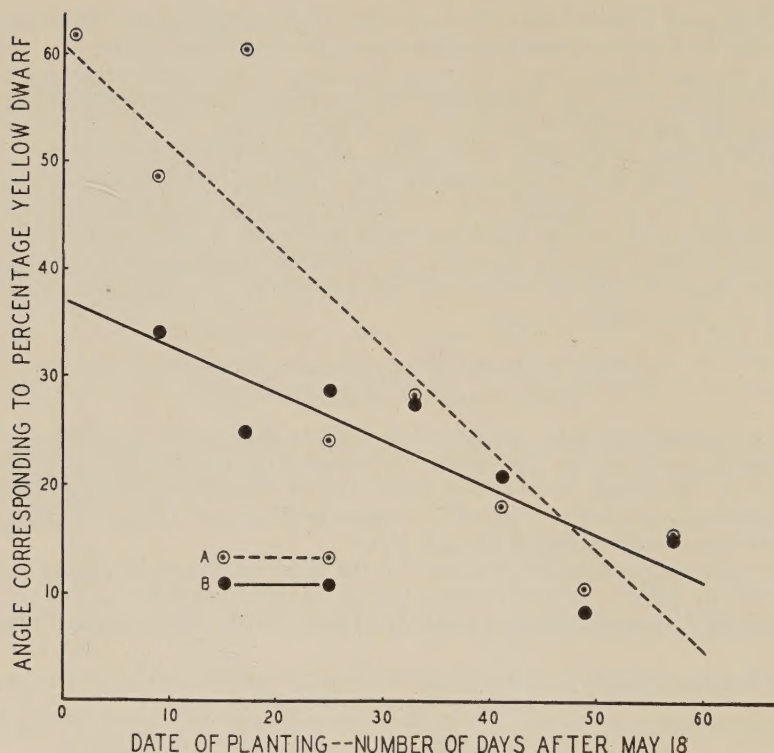


FIGURE 2. CORRELATION BETWEEN YELLOW-DWARF INFECTION, AND DATE OF PLANTING GREEN MOUNTAIN POTATOES ON TWO FARMS, STEUBEN COUNTY, 1939

percentage of infected plants in the Green Mountain variety and that of infected plants in either the Chippewa or the Katahdin was highly significant (odds greater than 999:1).

It may be concluded from these experiments that yellow dwarf cannot be controlled by planting a susceptible variety on any date that is suitable for commercial production of potatoes in west central New York. The varieties Chippewa and Katahdin retained their ability to escape yellow dwarf on all the dates of planting.

EFFECT, ON THE SPREAD OF YELLOW DWARF, OF ISOLATING SMALL PLOTS OF GREEN MOUNTAIN POTATOES IN DIFFERENT CLOVER FIELDS

A survey reported by Mader (1937) indicated that there was a greater spread of yellow dwarf from some clover fields than from others. Because clover is one of the most important agricultural crops in west central New York, further information was sought. Potatoes were planted in isolated areas in different clover fields and the spread of the disease was recorded.

One experiment was conducted in 1938 on three farms in second-year-clover fields.⁶ During 1939 one experiment was conducted on three farms

⁶Clover was planted in 1937.

in first-year-clover fields while another experiment was conducted on two farms in third-year-clover fields. The potatoes were harvested in the fall and later indexed.

In 1938 there was very little spread of yellow dwarf to the potatoes isolated in the Medium Red and Mammoth Red clover fields as compared with a moderate spread to the potatoes isolated in the Alsike clover fields (table 3).

There was a relatively high current-season spread of yellow dwarf to potatoes from all the different clover fields in 1939 (table 3). It was con-

TABLE 3. EFFECT ON THE SPREAD OF YELLOW DWARF, OF ISOLATING SMALL PLOTS OF GREEN MOUNTAIN POTATOES IN DIFFERENT CLOVER FIELDS, STEUBEN COUNTY*

Kind	1938-1939		1939-1940			
	Second-year clover		First-year clover		Third-year clover	
	Cooperators C, K, and U		Cooperators A, C, and K		Cooperators C and K	
	Yellow-dwarf-infected plants		Yellow-dwarf-infected plants		Yellow-dwarf-infected plants	
	Mean angle from original percentages†	Percentage transformed from angle	Mean angle from original percentages‡	Percentage transformed from angle	Mean angle from original percentages‡	Percentage transformed from angle
Medium Red.....	8.29	2.1	49.74	58.2	24.11	16.7
Mammoth Red.....	7.66	1.8	28.80	23.2	36.77	35.8
Alsike.....	22.52	14.7	42.09	44.9	37.98	37.9

*Planted in clover fields 1938 and 1939; indexed, greenhouse, Ithaca, New York, 1939 and 1940, respectively.

†Difference in angle for significance, odds of 19:1 = 12.21; odds of 99:1 = 20.26.

‡Difference in angle not significant.

cluded that yellow dwarf could not be controlled, under the set of environmental conditions that existed during the summer of 1939, by changing from Medium Red to either Alsike or Mammoth Red clover, as suggested by Mader (1937).

EFFECT, ON THE SPREAD OF YELLOW DWARF, OF ISOLATING SMALL PLOTS OF GREEN MOUNTAIN POTATOES IN DIFFERENT COMMERCIAL FIELDS

Small plots of Green Mountain potatoes were located in the centers of various fields to obtain information on the possible sources of yellow-dwarf inoculum.

In 1938 sixteen small plots of potatoes were isolated in different commercial fields on six farms; in 1939 thirty plots were similarly located on three farms. The tubers were harvested and later indexed.

With the exception of the plot of potatoes isolated in the dense wood in 1939, there was a spread, medium to high, of yellow dwarf to all the plots (table 4).

The extent to which the clover leafhoppers became viruliferous by feeding on the various crops, as compared with feeding on susceptible weeds in those fields, is not known. Some of the leafhoppers may have migrated

TABLE 4. EFFECT, ON THE SPREAD OF YELLOW DWARF, OF ISOLATING SMALL PLOTS OF GREEN MOUNTAIN POTATOES IN DIFFERENT COMMERCIAL FIELDS, STEUBEN AND LIVINGSTON COUNTIES

Commercial fields		Yellow-dwarf-infected plants	Range yellow-dwarf-infected plants
Kind	Number plots		
1938-39*		<i>Per cent</i>	<i>Per cent</i>
Oats.....	6	24.4	18.0-38.8
Alfalfa.....	3	29.5	20.6-68.2
Clover.....	6	45.4	25.8-68.4
Meadow†.....	1	85.9	.....
1939-40‡			
Wood (dense)...	1	0.0	.....
Corn.....	1	8.7	.....
Meadow.....	12	23.4	2.7-48.1
Clover.....	11	39.7	1.8-95.7
Oats.....	3	47.1	25.0-63.4
Alfalfa.....	2	50.0	46.2-51.3

*Planted in the centers of commercial fields 1938; cooperators, A, B, C, U, V, and W; indexed, greenhouse, Ithaca, New York, 1939.

†Meadow = old clover fields.

‡Planted in the centers of commercial fields 1939; cooperators, A, C, and D; indexed, greenhouse, Ithaca, New York, 1940.

from one field to another. This experiment indicated that weeds may be an important source of inoculum, because high percentages of infected plants were obtained in progenies of potatoes grown in old weedy meadows containing very little clover or other legumes.

COMPARATIVE SPREAD OF YELLOW DWARF TO KATAHDIN AND GREEN MOUNTAIN POTATOES ISOLATED IN VARIOUS COMMERCIAL FIELDS

This experiment was conducted to determine whether Katahdin potatoes would escape infection when grown in various fields. Katahdin and Green Mountain potatoes were grown in 25-hill plots in 11 fields on 3 farms. The potatoes were dug in October and the tubers were indexed.

From 0.0 to 9.2 per cent of infected plants occurred in the samples from the various Katahdin plots as compared with 5.6 to 61.9 per cent in the samples from the Green Mountain plots (table 5). The difference in the percentage of infected plants for the two varieties was highly significant (odds greater than 999:1). In general, Katahdin escaped yellow-dwarf infection fairly well when grown under the various sets of conditions.

EFFECT OF SHIELDING CROPS, ON THE SPREAD OF YELLOW DWARF

Two experiments were conducted in 1939 to determine the value of shielding crops in the control of yellow dwarf.

The shielding plots, 20 feet wide and 100 feet long, were each replicated twice and laid out along the side of a commercial field of potatoes. In the check plots, the meadow was next to the potatoes. During October, a representative sample of 100 tubers was taken from the central 75 feet of the commercial row of potatoes next to each shielding plot. These samples were stored and then indexed.

TABLE 5. COMPARATIVE SPREAD OF YELLOW DWARF TO KATAHDIN AND GREEN MOUNTAIN POTATOES ISOLATED IN VARIOUS COMMERCIAL FIELDS, 1939-40*

Cooperator	Number of fields	Variety Katahdin		Variety Green Mountain	
		Yellow-dwarf-infected plants	Range yellow-dwarf-infected plants	Yellow-dwarf-infected plants	Range yellow-dwarf-infected plants
A	3	<i>Per cent</i> 0.6	<i>Per cent</i> 0.0-1.4	<i>Per cent</i> 37.8	<i>Per cent</i> 5.6-61.9
C	6	3.8	0.0-9.2	35.4	10.2-54.2
D	2	0.0	.....	36.5	31.0-40.0
Mean angle from original percentages†		5.18		33.18	
Percentage transformed from angle		0.82		29.9	

*Planted, June 1939; indexed, greenhouse, Ithaca, New York, 1940.

†Difference in angle between Katahdin and Green Mountain significant, odds greater than 999:1.

Highly significant reductions in infected plants were obtained by the use of the shielding crops soybeans, field peas, and mangels as compared with the check. There was no significant difference in infection between any of these crops and an equivalent width of potatoes (table 6).

TABLE 6. EFFECT OF SHIELDING CROPS ON THE SPREAD OF YELLOW DWARF, LIVINGSTON AND STEUBEN COUNTIES, 1939-40*

Shielding crop†	Cooperator D		Cooperator C	
	Yellow-dwarf-infected plants		Yellow-dwarf-infected plants	
	2 replicates		2 replicates	
	Mean angle from original percentages	Percentage transformed from angle	Mean angle from original percentages	Percentage transformed from angle
Soybeans.....	29.02	23.5	18.56	10.1
Field peas.....	29.16	23.7	.....	.....
Buckwheat.....	38.79	39.2	.....	.....
Mangels.....	.....	.....	16.88	8.4
Potatoes.....	32.87	29.5	17.82	9.4
None, check.....	41.86	44.5	28.41	22.6
Odds of 19:1.....	4.26		5.43	
Odds of 99:1.....	7.06		9.97	
Odds of 999:1.....	13.20		22.10	

*Planted May and June, respectively, 1939; indexed, Ithaca, New York, 1940.

†A barrier of 20 feet between the meadow and the potatoes.

‡Difference in angle for significance.

EFFECT, ON THE SPREAD OF YELLOW DWARF, OF THE APPLICATION OF COMMERCIAL FERTILIZER

Two experiments were conducted in 1939 to determine whether the application of varying amounts of commercial fertilizer would have any effect on the spread of yellow dwarf.

Replicated plots were laid out in commercial fields of Rural potatoes next to meadows. Commercial fertilizer, 5-10-5, was added to the soil at the rate of 667 pounds, 1333 pounds, and 2000 pounds per acre. In October,

representative samples of tubers were taken from the potatoes in the various treatments and in the check plots. These samples were stored and then indexed.

A moderate amount of yellow dwarf occurred in the samples from all the treatments (table 7). There was no significant difference in the number of infected plants in any of the treatments as compared with the check.

TABLE 7. EFFECT, ON THE SPREAD OF YELLOW DWARF, OF THE APPLICATION OF COMMERCIAL FERTILIZER, STEUBEN COUNTY, 1939-40*

Rate of appli- cation per acre†	Cooperator B		Cooperator C	
	Yellow-dwarf-infected plants			
	3 replicates		2 replicates	
	Mean angle from original percentages‡	Percentage trans- formed from angle	Mean angle from original percentages‡	Percentage trans- formed from angle
<i>Pounds</i>				
None, check.....	24.38	17.0	22.98	15.2
667.....	23.70	16.2	22.18	14.2
1333.....	22.81	15.0	22.87	15.1
2000.....	26.15	19.4	24.50	17.2

*Planted June 1939; indexed, Ithaca, New York, 1940.

†5-10-5 fertilizer was applied by hand and then cultivated into the soil.

‡Difference in angle not significant.

EFFECT OF SPRAYING OR DUSTING POTATOES ON THE SPREAD OF YELLOW DWARF

Two experiments were conducted in 1939 to determine the relative value of spraying or dusting Rural potatoes in the control of yellow dwarf, under conditions in which a moderate to high current-season spread of the disease might be expected.

The dust treatments, pyrethrum and celite, rotenone and talc (each pair mixed in the ratio of 1 to 3) and sulfur were applied with a hand-operated duster at the rate of 100 pounds per acre. The spray treatments, bordeaux mixture, 8-4-50, and calcium arsenate, 8-50, were applied with a knapsack sprayer at the rate of 100 gallons per acre. The first application of dusts and sprays was made when approximately two-thirds of the potato plants had emerged. Ten subsequent applications were made at regular intervals up to the date of killing frost.

The potatoes were dug during October and a representative sample of 100 tubers was taken from each plot. The samples were indexed the next year.

Significant reductions in the number of infected plants were obtained by the treatments pyrethrum-celite, sulfur, and bordeaux mixture as compared with their check in the first experiment and for bordeaux mixture as compared with its check in the second experiment (table 8). There was, however, sufficient yellow dwarf to make the tubers unsuitable for seed.

The data of Mader and Watkins (1938) and Watkins (1939) in which

TABLE 8. EFFECT OF SPRAYING OR DUSTING POTATOES ON THE SPREAD OF YELLOW DWARF, STEUBEN COUNTY, 1939-40*

Treatment†	Rate per acre	Cooperator B		Cooperator C	
		Infected plants		Infected plants	
		4 replicates		3 replicates	
		Mean angle from original percentages	Percentage transformed from angle	Mean angle from original percentages	Percentage transformed from angle
Pyrethrum 25-celite 75	100 lbs.	21.92	13.9	.....	.....
Sulfur	100 lbs.	22.98	15.2	.....	.....
Bordeaux mixture 8-4-50	100 gal.	27.43	21.2	18.13	9.7
Calcium arsenate 8-50...	100 gal.	29.98	25.0	.....	.....
Rotenone 25-talc 75....	100 lbs.	30.88	26.3	.....	.....
None, check.....	.....	30.60	25.9	22.89	15.1
Odds of 19:1‡.....	.....	2.86	.....	4.00	.....
Odds of 99:1.....	.....	3.95	.....	9.23	.....
Odds of 999:1.....	.....	5.46	.....	29.38	.....

*Planted June 1939; indexed, Ithaca, New York, 1940.

†The various treatments were applied with a knapsack sprayer or a hand duster.

Pyrethrum dust—Activated "A" containing 0.5 per cent pyrethrins.

Celite—209.

Sulfur—Mike.

Rotenone—0.75 per cent.

Talc—Loomkill.

‡Difference in angle for significance.

reductions in the amount of yellow dwarf were obtained by spraying or dusting were substantiated.

EFFECT OF ROGUING POTATOES ON THE SPREAD OF YELLOW DWARF

An experiment was conducted to determine whether or not roguing of infected plants would reduce the subsequent spread of yellow dwarf. Plots were laid out, next to a meadow, in a commercial field of Rural potatoes. In the first treatment the tuber-borne infected plants were rogued, in the second treatment the current-season infected plants were rogued, while in the third treatment all infected plants were rogued. The different treatments and the check were replicated three times. Roguing was done on seven dates during the summer. The tuber-borne, yellow-dwarf-infected plants which were not rogued either died early or they produced principally very small tubers. The potatoes were dug in October and a representative sample of approximately 100 medium sized tubers was taken from each plot. These samples were indexed the following year.

There was no significant difference in infection when tuber-borne, yellow-dwarf-infected plants were rogued (table 9). A significant reduction in infection was obtained by roguing current-season, yellow-dwarf-infected plants. There was, however, still sufficient yellow dwarf present to make the tubers unfit for seed. The results of this experiment were in agreement with those obtained by Black (1937).

EFFECT OF DATE OF HARVESTING ON THE CONTROL OF YELLOW DWARF

Because considerable time occurs between inoculation of the plant and infection of the tubers, two experiments were conducted to determine the effect of early harvesting on the control of yellow dwarf.

TABLE 9. EFFECT OF ROGUING POTATOES ON THE SPREAD OF YELLOW DWARF, STEUBEN COUNTY, 1939-40*

Type of roguing, 1939†	Yellow-dwarf-infected plants 1939‡		Yellow-dwarf-infected plants	
	Tuber-borne	Current-season	Mean angle from original percentages§	Percentage transformed from angle
	<i>Per cent</i>	<i>Per cent</i>		
Tuber-borne.....	10.1	13.3	27.18	20.9
Current-season.....	10.7	10.1	21.40	13.3
Tuber-borne and current-season.....	10.8	13.6	23.12	15.4
None, check.....	10.1	11.8	26.20	19.5

*Planted June 26, 1939; three replicates; Cooperator C; indexed, Ithaca, New York, 1940.

†Roguing was done on July 15, 23, and 31; August 8, and 25; and September 8 and 27, 1939.

‡The stand in the various plots varied from 185 to 202 plants prior to roguing. The percentage of current-season yellow dwarf is based on the total stand less the tuber-borne yellow dwarf.

§Difference in angle between roguing and not roguing tuber-borne yellow dwarf not significant.

Difference in angle between roguing and not roguing current-season yellow dwarf significant, odds greater than 19:1.

Plots were laid out next to meadows in two commercial fields of Rural potatoes. The vines were pulled in triplicate plots on differing dates (table 10). During the latter part of October the potatoes were dug and weighed, and a representative sample of tubers was taken from each plot. The samples were stored and then indexed.

There was a significant reduction in the percentage of infected plants for the dates August 23 and September 8 as compared with their check (October 14), in the first experiment; and for August 23 as compared with its check in the second experiment (table 10). The yield was reduced to such an extent that this method of control would not be practical for this variety (table 10).

TABLE 10. EFFECT OF DATE OF HARVESTING ON THE CONTROL OF YELLOW DWARF IN RURAL POTATOES, STEUBEN COUNTY, 1939-40*

Date of harvesting†	Yield in bushels per acre	Yellow-dwarf-infected plants	
		Mean angle from origi- nal percentages	Percentage transformed from angle
	Cooperator C, 3 replicates		
August 23.	17.3	19.23	10.8
September 8.	34.4	20.91	12.7
September 24.	74.4	25.43	18.4
October 14.	106.5	28.01	22.1
Odds 19:1‡.	17.6	3.41	....
99:1.	26.7	5.16	....
999:1.	42.9	8.30	....
	Cooperator X, 3 replicates		
August 23.	11.2	19.65	11.3
September 16.	37.3	27.23	20.9
October 14.	98.8	29.34	24.0
Odds 19:1‡.	14.0	3.22	....
99:1.	23.2	5.34	....
999:1.	43.4	9.98	....

*Planted June 1939, indexed, Ithaca, New York, 1940.

†Date of pulling vines. The tubers were dug after the killing frost of October 14.

‡Difference in bushels per acre and angle, respectively, for significance.

COMPARATIVE SPREAD OF YELLOW DWARF TO THE MARGINS OF RURAL
POTATO FIELDS ADJOINING DIFFERENT COMMERCIAL CROPS

Seventy-four samples of potatoes were taken from the margins of Rural potato fields on eleven farms in 1939 to determine the comparative current-season spread of yellow dwarf from different crops to commercial fields of potatoes (table 11). One sample of tubers was taken from the margin

TABLE 11. COMPARATIVE SPREAD OF YELLOW DWARF TO THE MARGINS OF RURAL
POTATO FIELDS NEXT TO DIFFERENT COMMERCIAL CROPS, STEUBEN COUNTY, 1939-40*

Adjoining crop		Yellow-dwarf-infected plants	Range yellow-dwarf-infected plants
Kind	Number†		
		<i>Per cent</i>	<i>Per cent</i>
Dense wood.....	4	2.5	1.9- 4.0
Field beans.....	3	7.0	4.9- 8.6
Field peas.....	1	9.9	
Road-pasture.....	3	10.1	6.7-16.3
Farmstead.....	2	11.3	4.5-18.2
Corn.....	6	12.6	8.7-17.4
Pasture.....	6	15.3	4.3-41.1
Young wood.....	1	16.1	
Oats.....	16	16.6	6.9-24.2
Buckwheat.....	3	18.6	17.0-22.6
Open orchard.....	1	18.6	
Alfalfa.....	2	21.4	4.3-38.7
Meadow‡.....	26	26.4	17.4-43.9

Odds that differences (averaged as angles) are significant§

	Number of comparisons	Odds
Meadow—dense wood.....	3	Greater than 999:1
Meadow—field beans.....	3	Greater than 19:1
Meadow—corn.....	6	Greater than 999:1
Meadow—pasture.....	4	Less than 19:1
Meadow—oats.....	8	Greater than 99:1
Meadow—buckwheat.....	3	Less than 19:1
Oats—corn.....	5	Greater than 99:1
Oats—pasture.....	4	Less than 19:1
Pasture—corn.....	3	Less than 19:1

*Planted May and June 1939; Cooperators—A, B, C, P, X, Y, Z, AA, BB, CC, and DD; dug, October 1939; indexed, Ithaca, New York, 1940.

†Number of samples taken, one for each crop bordering on each side of the potato field.

‡Second-year or older clover.

§All combinations of two which were represented in pairs on three or more farms.

of each potato field bordering each crop. The samples were taken near the center of the margin to reduce the effect of the spread of yellow dwarf from the other sides of the field. The samples were stored and then indexed.

The data were combined in groups according to the particular crops (table 11). The average percentages of infected plants varied from 2.5 for samples taken next to a dense wood to 26.4 for samples taken in the part of the field bordering meadows.

Statistical analysis was used for the data from all paired combinations of crops which occurred on three or more farms. There were significantly more infected plants in the samples taken next to the meadow than in those taken next to a dense wood, field beans, corn, or oats. There was no significant difference in infection between samples taken in the part of the field bordering meadows as compared with those taken next to either pasture or buckwheat fields. The difference in percentage of infected plants between

those samples taken next to the oat fields and those taken next to the corn fields was highly significant.

COMPARATIVE SPREAD OF YELLOW DWARF TO THE MARGINS AND
CENTERS OF RURAL POTATO FIELDS

An experiment was conducted to determine whether or not yellow dwarf could be satisfactorily controlled by saving potatoes for seed from the centers of potato fields. Representative samples of tubers were saved from the margins and the centers of 10 Rural fields on 8 farms during 1939. These samples were indexed during 1940.

The percentages of infected plants varied from 9.1 to 33.8 for the progeny of the samples from the margins, while they varied from 4.2 to 44.0 for the ones from the centers (table 12). In one narrow field there was actually

TABLE 12. COMPARATIVE SPREAD OF YELLOW DWARF TO THE MARGINS AND CENTERS OF RURAL POTATO FIELDS, STEUBEN COUNTY, 1939-40*

Cooperator	Margin		Center	
	Yellow-dwarf-infected plants	Angle from percentage	Yellow-dwarf-infected plants	Angle from percentage
	<i>Per cent</i>		<i>Per cent</i>	
CC-1.....	9.1	17.56	6.6	14.89
CC-2.....	10.4	18.81	6.9	15.23
B-1.....	15.4	23.11	6.1	14.30
Z.....	19.3	26.06	13.5	21.56
Y.....	23.7	29.13	6.1	14.30
A.....	24.1	29.40	14.3	22.22
AA.....	24.2	29.47	8.3	16.74
B-2.....	28.6	32.33	4.2	11.83
DD.....	29.1	32.65	10.0	18.44
EE.....	33.8	35.55	44.0	41.55
Mean angle from original percentages†		27.41	...	19.11
Percentage transformed from angle		21.2	...	10.7

*Planted May and June, 1939; dug, October, 1939; indexed, Ithaca, New York, 1940.

†Difference in angle between margin and center samples is significant, odds greater than 99:1.

less yellow dwarf in the progeny of the sample of tubers from the margin than in that from the center. This difference, however, was not statistically significant. The average percentage of infection in the progeny of the samples from the margins was 21.2 as compared with 10.7 for the samples from the centers. The difference was highly significant.

In general, yellow dwarf can be controlled only partially by saving tubers for seed from the center of the field as compared with saving tubers from the margin.

A SUMMARY OF OBSERVATIONS MADE DURING A SURVEY OF FARMS IN
STEUBEN COUNTY WHERE CERTIFIED RURAL SEED
WAS INTRODUCED IN 1939

During the spring of 1939 a quantity of certified Rural potatoes was introduced into Steuben County, and a number of potato growers purchased from five to twenty bushels of this seed. These potato growers planned to

plant only a small portion of their potato acreage with certified seed during 1939, but to plant, with the progeny of this certified seed, 50 to 100 per cent of their acreage of potatoes in 1940.

A survey was undertaken during the summer of 1940 to determine how successful this method had been in the control of yellow dwarf, and whether it had been more successful on some farms than on others.

Previous data had shown that the virus may overwinter in various clovers, in some weeds, in the clover leafhoppers, and in infected tubers. It had been observed that the source, from which the main spread of the virus occurred, was outside the potato field, because the highest percentage of infected plants was observed often in the outside rows. For this reason special attention was directed in this survey to the relation between the location of the planting of these samples in 1939 and the amounts of the disease observed in the progeny in 1940. The results were summarized according to where the certified seed was planted on the farm in 1939; that is, whether it was planted on the side of the main field of potatoes, in a strip through the center of the potato field, or in a separate field by itself. The percentages of infected plants observed in 1940 represented the spread of the disease into the fields during the previous year. The 43 farms in which a few bushels of certified Rural potatoes were planted in 1939 were selected at random in the northern one-third of Steuben County.

It was found that on 19 of these farms the introduced certified seed had been planted on the outside of the potato fields in 1939. The average percentages of infected plants observed in the progeny from the certified as compared with the non-certified potato seed were 19.0 and 12.9 respectively (table 13). The difference was statistically significant. As might have been

TABLE 13. A SUMMARY OF OBSERVATIONS MADE IN A SURVEY OF FARMS IN STEUBEN COUNTY WHERE CERTIFIED RURAL SEED WAS INTRODUCED IN 1939*

Location of certified in relation to non-certified Rural potatoes in 1939	Number of farms surveyed	Results of survey in 1940†			
		Progeny from certified seed		Progeny from non-certified seed	
		Yellow-dwarf-infected plants		Yellow-dwarf-infected plants	
		Average	Range	Average	Range
Side of field‡.....	19	<i>Per cent</i> 19.0	<i>Per cent</i> 3-53	<i>Per cent</i> 12.9	<i>Per cent</i> 3-24
Middle of field.....	8	12.9	6-21	19.0	7-34
Separate field.....	8	16.9	5-44	14.9	7-28
Average.....	..	17.1	.....	14.8	....
Planted in various ways but only progeny from certified seed saved for planting in 1940.....	8	23.5	16-41	...	....

*Commercial fields in this experiment were selected at random but predominantly in the section of Steuben County where yellow dwarf was most abundant. Only fields where the cooperator planted a few bushels of certified Rurals in 1939 were included.

†Difference between progeny of certified and non-certified potatoes:

Side of field significant, odds greater than 19:1.

Middle of field significant, odds greater than 19:1.

Separate field not significant, odds less than 19:1.

‡Side of field in this experiment also includes any place where not more than six rows of non-certified potatoes were planted between the certified seed and the edge of the potato field.

anticipated, not all the figures for the different farms were consistent in this respect. In 4 of the 19 farms there was the same number of infected plants from the progeny of the certified seed as of the non-certified seed. In 3 of the 19 there were fewer infected plants from the progeny of the certified seed than from the progeny of the non-certified seed. In these latter instances the certified seed may have been planted on the side of the field where little current-season spread of yellow dwarf occurred during 1939.

In 8 of the 43 farms the certified potatoes were planted in a strip through the center of the potato field. The results obtained on these farms were reversed. The progeny from the certified potatoes averaged 12.9 per cent of infected plants while those from the non-certified averaged 19.0 per cent (table 13). This difference was significant. It may be concluded that the location of the potatoes in 1939 was the main factor in determining the amount of current-season spread of yellow dwarf.

On 8 of the farms the certified and non-certified potatoes were planted in separate fields in 1939. In 1940 the average percentage of infected plants was 16.9 for the progeny from the certified seed as compared with 14.9 for the progeny from the non-certified seed. There was no significant difference in the amount of infection on the eight farms.

On 8 of the farms, only progeny from the certified seed was planted in 1940. Because the average percentage of infected plants was 23.5, no advantage had been gained by planting only progeny from the certified seed.

THE SPREAD OF YELLOW DWARF FROM ADJOINING FIELDS INTO POTATOES

Two experiments were conducted in 1938 and three in 1939 to determine the relative current-season spread of yellow dwarf at varying distances from the margins of potato fields. Representative samples of tubers were taken from rows adjoining meadows and other crops, and from other rows within the potato fields. These were stored and then indexed.

These data plotted with the logarithm of the percentages of infected plants on the ordinate against the distance in rows from the meadows or other crops on the abscissa approximated straight lines (figure 3).

The data from these experiments indicated that the clover leafhopper, which is the vector for this disease, migrated according to the laws of diffusion; that it occurred naturally outside the potato fields in question; and that spread from current-season-infected potato plants was of minor importance. The potential spread of yellow dwarf indicated by the percentage of infected plants from the sample in the outside row, and the depth of penetration into the potato field, indicated by the slope of the regression line, probably vary with such factors as population density in the adjoining fields, percentage of viruliferous clover leafhoppers, prevailing winds, and food supply.

INCIDENCE OF YELLOW DWARF IN PLANTS FROM TUBERS OF VARIOUS SIZES

Four experiments were conducted to determine whether there was any correlation between size of tuber and infection in the progeny of healthy potato plants exposed to current-season infection. In the first experiment, 50 hills were selected which showed current-season yellow dwarf at time

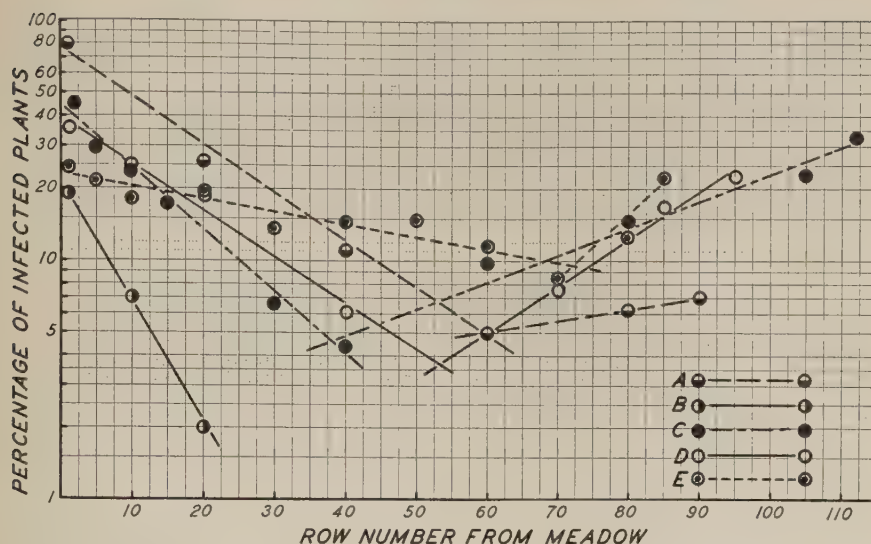


FIGURE 3. SPREAD OF YELLOW DWARF FROM ADJOINING FIELDS INTO POTATOES (SHOWN ON SEMI-LOGARITHM PAPER), STEUBEN AND LIVINGSTON COUNTIES; A AND B, 1938; C, D, AND E, 1939

In all the fields except B, the potatoes were taken from one side of the field to the other. The two sides of the field were bordered as follows: A, meadow — narrow strip of meadow beyond which was a cattle lane; B, meadow; C, meadow — meadow; D, meadow — buckwheat; E, meadow — oats.

of digging. In the second experiment 50 apparently healthy hills were selected in the same area. In experiments 3 and 4 successive hills were dug adjacent to different meadows. The tubers were stored, weighed, and then indexed in the greenhouse.

The data for each experiment were classified according to the size of the tuber and analyzed by the Chi-square test (table 14). No significant differ-

TABLE 14. INCIDENCE OF YELLOW DWARF IN PLANTS FROM TUBERS OF VARIOUS SIZES

Experiment*	Number of tubers				P†
	Infected		Healthy		
	Total	Average weight	Total	Average weight	
1	162	41.3	39	44.4	0.82
2	42	55.7	161	57.8	0.40
3	175	79.3	44	80.4	0.22
4	159	108.3	100	106.1	0.72

*Experiments 1, 2, and 3; variety, Rural; planted June 1938.

Experiment 4; variety, Green Mountain; planted May 1939.

The tubers in experiment 1 represent 50 hills dug at random which apparently showed current-season yellow-dwarf symptoms. The tubers in experiment 2 represent 50 hills dug at random in the same area but which appeared healthy.

†P = the probability of obtaining as variable a set of numbers of healthy and diseased plants, as were obtained in these experiments, by random selection from a population having a uniform amount of disease in the different size classes.

The tubers were divided into different classes by weight in grams.

Differences, as judged by the Chi-square test, in amount of yellow dwarf in the various classes for the different experiments not significant.

Difference, as judged by the Chi-square test, in relative amount of yellow dwarf between experiments 1 and 2 significant, odds greater than 999:1.

ences were found in the relative number of infected plants in the groups of different sizes. The average weights of the infected and healthy tubers for each experiment were approximately the same (table 14). The difference in the relative amount of yellow dwarf in experiments 1 and 2 was highly significant (odds greater than 999:1).

Planting tubers of selected size from plants previously exposed to current-season infection would be of no value in the control of yellow dwarf. These experiments confirmed those of Black (1937).

COMPARISON OF THE NUMBER OF YELLOW-DWARF-INFECTED PLANTS OBTAINED FROM DIFFERENT SECTIONS OF RURAL TUBERS

This experiment was conducted to determine the extent of infection in tubers from plants exposed to heavy current-season infection. Rural potatoes were dug in October 1938 in a field of potatoes adjoining a meadow where current-season spread had been observed.

In 1939 each tuber was cut into three equal parts. The stem-end section was separated by a transverse cut and the seed end of the tuber was divided longitudinally into two parts. These were planted in pots in the greenhouse. The plants were observed closely and notes taken at various times during their growth. The greenhouse was fumigated several times and during the experiment no clover leafhoppers were observed on the plants. In a few instances where one or two plants were missing, the other plants from the same tuber were disregarded in classifying the data.

In 135 cases all three sections of the tuber produced infected plants, in 16 cases one or two sections produced infected plants, and in 44 cases all

TABLE 15. COMPARISON OF THE NUMBER OF YELLOW-DWARF-INFECTED PLANTS OBTAINED FROM DIFFERENT SECTIONS OF RURAL TUBERS, STEUBEN COUNTY, 1938-39*

Classification of sections of tubers†	Triplicate sets of plants	
	Number‡	Per cent§
All three sections infected.....	135	89.4
Stem end infected		
Seed end		
Both sections healthy.....	7	4.6
One section infected, the other healthy.....	5	3.3
Stem end healthy		
Seed end		
Both sections healthy.....	0	0.0
One section infected, the other healthy.....	4	2.6
Total.....	151	....
All three sections healthy.....	44	....

*Planted June, 1938; Cooperator C, Steuben County; dug adjacent to meadow, October; indexed, greenhouse, Ithaca, New York, 1939.

†Each tuber was cut into three equal parts. The stem end section was first separated by a transverse cut; then the seed end of the tuber was divided longitudinally into two sections.

‡In a few instances where one or more plants were missing, the other plants from the same tuber were disregarded in classifying the data.

§Calculated on the total number in which one or more plants from the same tuber showed yellow dwarf.

the sections produced healthy plants (table 15). Among the tubers that were partially infected, there were 12 in which the stem-end piece was infected as compared with 4 in which it was healthy.

The data confirmed experiments of Walker and Koch (1934) and Black

(1937) in which they found that yellow dwarf and healthy plants may develop from different sections of the same tuber.

These plants were harvested and stored, and a representative number of the tubers were indexed in the greenhouse. All the tubers from healthy plants produced healthy plants while the tubers from infected plants produced infected plants.

The suggestion of Walker and Larson (1939) that potato plants may carry the virus during the second season without showing any symptoms was not confirmed in this greenhouse experiment.

DIAGNOSIS OF YELLOW DWARF BY SLICING HALF-TUBERS
COMPARED WITH DIAGNOSIS BY INDEXING

The purpose of these experiments was to get more information on the value of detecting infection by slicing as compared with indexing tubers. One-half of each tuber was sliced with a hand-operated potato-chip machine. If one or more typical rust-colored spots were observed in a half-tuber, the yellow dwarf was diagnosed by slicing. The other half-tuber was planted in the greenhouse. If the plant that grew from this half showed symptoms

TABLE 16. DIAGNOSIS OF YELLOW DWARF BY SLICING HALF-TUBERS COMPARED WITH
DIAGNOSIS BY INDEXING, STEUBEN AND LIVINGSTON COUNTIES

Classification per cent of infected plants, by indexing	1938-39* Number of infected plants			1939-40† Number of infected plants		
	Indexing	Slicing	Factor‡	Indexing	Slicing	Factor‡
0.0-10	40	29	1.38	29	18	1.61
10.1-20	105	67	1.57	99	62	1.60
20.1-30	120	79	1.52	154	103	1.50
30.1-40	127	96	1.32	138	119	1.16
40.1-50	83	46	1.80	180	141	1.28
50.1-60	25	18	1.39	242	183	1.32
60.1-70	24	15	1.60	141	111	1.27
70.1-80	69	47	1.47	156	129	1.21
80.1-90	90	63	1.43	...	...	...
90.1-100	...	...	...	112	109	1.03
Total.....	683	460	1.48	1251	975	1.28
Analysis by cooperator						
D	...	...	...	327	304	1.08
A	117	84	1.39	219	183	1.20
W	39	28	1.39	...	...	...
U	43	29	1.48	...	...	...
C	207	139	1.49	460	339	1.36
B	215	143	1.50	...	...	...
K	20	12	1.67	245	149	1.64
V	42	25	1.68	...	...	...

*Samples from small isolated plots of Green Mountain potatoes in 1938; sliced and indexed, greenhouse, Ithaca, N. Y., 1939.

Judged by the Chi-square test, the differences between the factors for the various classes were not significant; nor were they for the different farms.

†Samples from small isolated plots of Green Mountain potatoes in 1939; sliced and indexed, greenhouse, Ithaca, N. Y., 1940.

Judged by the Chi-square test, the differences between the factors for the various classes were significant, odds greater than 99:1.

Judged by the Chi-square test, the differences between the factors for the different farms were significant, odds greater than 99:1.

Judged by the Chi-square test, the differences between the factors for the totals for 1938-39 and 1939-40 were significant, odds greater than 99:1.

‡Yellow dwarf diagnosed by indexing

Yellow dwarf diagnosed by slicing

of the disease, the yellow dwarf was diagnosed by indexing. A factor was calculated as follows:

$$\frac{\text{Number of tubers diagnosed (as infected) by indexing}}{\text{Number of tubers diagnosed (as infected) by slicing}}$$

In the first experiment, 60 samples of tubers from small isolated plots of potatoes on seven farms were used. These were divided into different classes based on the percentage of infected plants by indexing (table 16). The factors for the different classes varied from 1.32 to 1.80, while the factors for the different farms varied from 1.39 to 1.68. There was no significant difference between calculated factors for either the classes or the farms. The calculated factor from the totals was 1.48.

In the second experiment, 55 samples of tubers from small, isolated plots of potatoes on 4 farms were diagnosed and classified as in the above experiment. The factors for the different classes varied from 1.03 to 1.61. There was some indication of greater accuracy in diagnosing yellow dwarf by slicing half-tubers in classes with higher percentages of infected tubers than in classes with lower percentages. The difference among the classes was highly significant. The factors for the different farms varied from 1.08 to 1.64. These differences were also highly significant. The calculated factor for the totals was 1.28. This was very close to the factor found by Black (1937).

There was a highly significant difference between the diagnosis of yellow dwarf by indexing and the diagnosis by slicing in the two experiments. Observations in the field suggested that the degree of accuracy in diagnosis of yellow dwarf by slicing half-tubers was correlated with the time the predominant current-season spread of the disease occurred the previous year.

DIAGNOSIS OF YELLOW DWARF BY SLICING HALF-TUBERS AS COMPARED WITH DIAGNOSIS BY MASHING THE SLICES AND INOCULATING LEAVES OF *NICOTIANA RUSTICA*; AND WITH DIAGNOSIS BY INDEXING

This experiment was conducted to find a quicker method of determining the percentage of infected tubers in a sample of potatoes. Such a method would be of practical value only if it were more accurate than the slicing method; therefore, the latter method was included as a check.

In 1939 a sample of tubers was dug in a field of Green Mountain potatoes next to a meadow. During 1940 one hundred tubers were selected at random from this lot. Each tuber was cut longitudinally. One half of it was sliced with a hand-operated potato-chip machine. Any half-tuber which showed one or more typical rust-colored spots was diagnosed as infected with yellow dwarf. The slices from each tuber were ground with a mortar and pestle. Three plants of *Nicotiana rustica* were dusted with carborundum, and then inoculated with sap and finely ground potato tissue. The other half of each tuber was planted as a check. The potato plants and *N. rustica* plants were observed during the experiment.

Thirty-nine of the tubers were diagnosed as infected with yellow dwarf by slicing while 30 of the tubers were diagnosed as infected by inoculating leaves of *N. rustica* (table 17). As 57 of the tubers were diagnosed as infected by indexing, neither of the other two methods was so satisfactory.

TABLE 17. DIAGNOSIS OF YELLOW DWARF BY SLICING HALF-TUBERS, AS COMPARED WITH DIAGNOSIS BY MASHING THE SLICES AND INOCULATING LEAVES OF *Nicotiana rustica*; AND WITH DIAGNOSIS BY INDEXING, 1939-40*

Diagnosis†	Total number of tubers	Number diagnosed as infected	Factor‡
Slicing half-tubers	100	39	1.46
Inoculating leaves of <i>N. rustica</i>	100	30	1.90
Indexing	100	57	...

*Variety, Green Mountain; planted May 1939; Cooperator D, Livingston County; dug next to a meadow, October; slicing, inoculating of *N. rustica*, and indexing, greenhouse, Ithaca, New York, 1940.

†Each tuber was cut longitudinally. One half of the tuber was sliced with a hand-operated potato-chip machine. The tubers which showed one or more typical rust-colored spots were diagnosed as infected. The slices from each tuber were then ground with a mortar and pestle. Three plants of *N. rustica* were dusted with carborundum and inoculated with the sap and finely ground tissue by rubbing with cheese-cloth. Half of each tuber was planted as a check.

‡Yellow dwarf diagnosed by indexing

Yellow dwarf diagnosed by slicing or by inoculating leaves of *N. rustica*

In this experiment, diagnosis of infection by slicing was more accurate than diagnosis by inoculating leaves of *N. rustica*.

DISCUSSION

Black (1937) and Mader (1937) reported an important association between red-clover fields and the spread of yellow dwarf to potatoes in New York. On the other hand, Walker and Larson (1939) found that potatoes contracted a medium to high percentage of the disease in Wisconsin, even though there were no clover fields in the vicinity. In these experiments in New York, a medium to high current-season spread of yellow dwarf has come from abandoned land and old meadows that contained predominantly weeds and grass with only a trace of clover. There has also been high spread of the disease from alfalfa fields and other crops. It has been found that some weeds are susceptible of the virus (Black, 1937, 1940; Hansing, 1942), and that others may also be susceptible. No conclusions can be drawn at present, therefore, as to the relative importance, as reservoirs of the virus, of clover, alfalfa, and other crops, in comparison with the weeds occurring in these crops.

The results of the variety tests confirmed the observations of Fernow and Black (1932) in that there was greater spread of yellow dwarf to the variety Green Mountain than to the variety Rural. These tests also confirmed those of Taylor (1938) in that there was less spread of the disease to the variety Russet Burbank than to different strains of Rural. The results in New York, however, varied considerably from those obtained by Walker and Larson (1939). In Wisconsin the percentages of yellow dwarf (infected plants and missing hills) for the following varieties were: Russet Burbank, 18, Warba, 28, Chippewa, 48, Houma, 53, Katahdin, 53, Rural (5 strains), 62, and Green Mountain, 70. In New York the results for the same varieties from the replicated experiment in the first variety test were: Katahdin, 0.0, Warba, 0.0, Chippewa, 1.0, Houma, 1.1, Russet Burbank, 11.0, Rural, 29.1, and Green Mountain, 52.2.

In Wisconsin the variety Russet Burbank had the lowest percentage of infected plants. In New York the varieties Katahdin, Warba, Houma, and Chippewa had significantly fewer infected plants than Russet Burbank. These differences may be due to the occurrence of different strains of the

virus (Black, 1940), or to some unknown factor. The varieties Rural and Green Mountain reacted similarly in both states.

SUMMARY

Experiments were conducted in Steuben, Livingston, and Tompkins counties to determine the most effective methods in the control of yellow dwarf of potatoes in New York state. The field experiments were conducted in cooperation with potato growers who were interested in finding a satisfactory control of this disease. Most of the experimental data were analyzed statistically, using equivalent angles of equal information.

In several replicated experiments the varieties Arran Banner, Chippewa, Golden, Houma, Jubel, Katahdin, Sebago, and Warba had fewer than 2 per cent of infected plants. The relative number of infected plants in the other varieties varied as follows: Russet Burbank, 2 to 11 per cent; Early Bovee, 18 to 28 per cent; Rural, 3 to 29 per cent; Green Mountain, 6 to 53 per cent; and Red McClure, which was included in one experiment, 52 per cent. Infected plants in the 20 United States Department of Agriculture potato-seedling varieties varied from 0 to 72 per cent.

In a survey of commercial fields of potatoes in Steuben County, Rural, Katahdin, and Chippewa had an average of 15.8, 0.14 and less than 0.1 per cent of infected plants respectively. The difference in infection between Rural and either Katahdin or Chippewa was highly significant (odds greater than 999:1).

A medium to high percentage of infected plants occurred in all the samples of Green Mountain potatoes, for each date of planting satisfactory for commercial production of potatoes in western New York. There was very little spread of yellow dwarf to either Chippewa or Katahdin for any date of planting. The difference in the spread of yellow dwarf to Green Mountain and either of the other two varieties was highly significant (odds greater than 999:1).

There was a medium to high, current-season spread of yellow dwarf to potatoes isolated in Medium Red, Mammoth Red, or Alsike clover fields.

A medium to high percentage of infected plants occurred in the samples from potato plots isolated in alfalfa, clover, meadow, oat, and corn fields. There was no spread of yellow dwarf to a plot of potatoes isolated in a dense wood.

The average current-season spread of yellow dwarf to plots of Green Mountain and Katahdin potatoes isolated in clover, meadow, and alfalfa fields was 29.9 and 0.82 per cent respectively. This difference was highly significant (odds greater than 999:1).

Narrow, shielding crops were no more effective than equivalent widths of potatoes in reducing the spread of yellow dwarf from adjoining crops into potato fields.

The application of varying amounts of commercial fertilizer did not have any effect on the control of yellow dwarf.

The application of pyrethrum and celite (mixed in the ratio of 1 to 3), sulfur, or Bordeaux mixture to potato plants significantly reduced the current-season spread of the disease. These materials, however, were only partially effective in the control of yellow dwarf.

Roguing tuber-borne, yellow-dwarf-infected plants was of no value in

reducing spread of the disease to healthy Rural potatoes. A partial but significant reduction of the disease was obtained by roguing current-season, yellow-dwarf-infected plants.

Yellow dwarf could be controlled to some extent by harvesting the vines of Rural potatoes 3 to 7 weeks prior to killing frost. The yield, however, was reduced to such an extent that this method was not practical for that variety.

There were significantly fewer infected plants in the progeny of samples from commercial Rural potato fields taken next to a dense wood, field beans, corn, and oats than from those samples taken next to meadows. There were also significantly fewer infected plants in the progeny from the center of commercial fields than from the margins of the same fields.

The practice potato growers have of planting a few bushels of certified Rural potatoes one year with the intention of using the progeny of these as seed potatoes the following year was not successful as a control measure against yellow dwarf. In general, it was more successful on farms where the certified seed was planted in a strip through the center of the main potato field than where it was planted near the margin or in a separate field.

The logarithms of the percentages of infected plants plotted against the distance in rows from the margins toward the centers of potatoes fields approximated straight lines.

There was no difference in the incidence of yellow dwarf in plants from tubers of varying sizes. Yellow dwarf and healthy plants sometimes developed from different sections of the same tuber. In a few cases the plant from the stem-end piece was healthy, while the plant from one of the two seed-end pieces was diseased.

In an experiment conducted in the greenhouse, potato plants did not carry the virus through the second season without showing symptoms of the disease.

Diagnosis of yellow dwarf by slicing half-tubers and observing the number that had typical rust-colored spots and multiplying by a factor was found to give an approximate indication of the number of tubers infected with the disease. Diagnosis of yellow dwarf by inoculating leaves of *Nicotiana rustica* with the sap and finely ground tissue of tubers was not so accurate as diagnosis by slicing half-tubers.

In west central New York, yellow dwarf was most effectively and satisfactorily controlled by the use of one of the varieties of potatoes that escaped infection under conditions in which there was a medium to high spread of the disease. Several of the other control measures were only partially effective.

REFERENCES

- BARRUS, MORTIER F., AND CHUPP, CHARLES C. Yellow dwarf of potatoes. *Phytopath.* 12: 123-132. 1922.
- BLACK, L. M. A study of potato yellow dwarf in New York. Cornell Univ. Agr. Exp. Sta. Memoir 209: 1-23. 1937.
- Strains of potato yellow-dwarf virus. *Amer. journ. bot.* 27: 386-392. 1940.
- EZEKIEL, MORDECAI. Methods of correlation analysis, p. 1-427. 1930.

- FERNOW, K. H., AND BLACK, L. M. Yellow dwarf in New York State. Amer. potato journ. 9: 116-117. 1932.
- FISHER, R. A., AND YATES, F. Statistical tables for biological, agricultural and medical research, p. 1-90. 1938.
- HANSING, E. D. New susceptibles of the potato yellow-dwarf virus. (Abstract.) Phytopath. 32: 7. 1942.
- HANSING, E. D., AND FRAMPTON, VERNON L. The dissemination of yellow dwarf of potatoes and its leafhopper vector, *Aceratagallia sanguinolenta*. (Abstract.) Phytopath. 30: 7. 1940.
- LARSON, R. H., AND WALKER, J. C. Yellow dwarf caused heavy potato losses in 1937. In What's new in farm science (Part II). Univ. Wisconsin Agr. Exp. Sta. Bul. 440: 42-43. 1938.
- MADER, E. O. Potato yellow dwarf and Medium Red clover. Amer. potato journ. 14: 293-295. 1937.
- MADER, E. O., AND WATKINS, T. C. Effects of bordeaux mixture on the control of yellow dwarf of potatoes. Phytopath. 28: 375. 1938.
- MUNCIE, J. H. Yellow dwarf disease of potatoes. Michigan Agr. Exp. Sta. Special bul. 260: 1-18. 1935.
- PEARSON, KARL. Tables for statisticians and biometricians. Part 1 [2nd ed.], p. 1-143. 1924.
- SNEDECOR, GEORGE W. Statistical methods applied to experiments in agriculture and biology [3rd ed.], p. 1-422. 1940.
- TAYLOR, CARLTON F. The incidence of yellow dwarf in potato varieties. Amer. potato journ. 15: 37-40. 1938.
- WALKER, J. C., AND KOCH, KARL. Poor potato stands traced to yellow dwarf. In Our changing agriculture. Univ. Wisconsin Agr. Exp. Sta. Bul. 428: 84-85. 1934.
- WALKER, J. C., AND LARSON, R. H. Yellow dwarf of potato in Wisconsin. Journ. agr. res. 59: 259-280. 1939.
- WATKINS, THOMAS C. Biological and control studies on the clover leafhopper. Journ. econ. ent. 32: 561-564. 1939.
- WHEELER, E. J. Inoculation of potato seedlings with the yellow dwarf virus. Amer. potato journ. 13: 221-223. 1936.